

# USING OF LOCAL INFORMATION FOR DIAGNOSING INTRANATAL ADVERSE CONDITONS BY PULSE OXIMETRY

Nilgun Guler<sup>1</sup>, Fikret Gurgen<sup>2</sup>, Gürkan Arikan<sup>3</sup>.

<sup>1</sup>Math. Eng. Dept, Yildiz Technical University, Besiktas, Istanbul/TURKEY

<sup>2</sup>Comp. Eng. Dept, Bogazici University, Bebek, 80815, Istanbul/TURKEY

<sup>3</sup>Gyn. and Obs. Dept, Graz University, Austria

{ <sup>1</sup>[guler@yildiz.edu.tr](mailto:guler@yildiz.edu.tr), <sup>2</sup>[gurgen@boun.edu.tr](mailto:gurgen@boun.edu.tr) }

**Abstract**—The study aims to use the predictive value of oxygen saturation for the determination of hypoxemia and acidosis by local information during intranatal fetal monitoring. For this purpose, we employ the measurement of umbilical artery (UA) and umbilical vein (UV) oxygen saturation and pH in an unselected population, and calculate preductal oxygen saturation at birth. The study analyzes umbilical cord blood samples of 1537 live-born singleton neonates. Oxygen saturation, pH and base excess were measured. Preductal oxygen saturation was computed with an empirical equation. Acidosis was defined as below the value of 7.09 for UA pH or  $-10.50$  mmol/L for base excess. Normality condition of the data is searched by Kolmogorov-Smirnov test. Then, the importance of individual indices is determined by using principal component analysis (PCA) method. A local decision technique, k-nearest neighbor (k-NN) method is employed for the indication of adverse conditions. Finally, RBF is used to combine the local information regions. It is verified that the base excess in UA is the most informative component and the local oxygen saturation information is valuable for the indication of adverse conditions.

**Keywords:** Fetal intranatal evaluation, pulse oximetry, k-NN, RBF

methods to detect fetal compromise are indirect and nonspecific. Theoretically, direct continuous noninvasive measurement of fetal oxygenation is desirable to improve intrapartum fetal assesment and, the specificity and detecting fetal compromise. The development of reflectance pulse oximetry has made it possible to measure fetal oxygen saturation during labor [1]. Intrapartal reflectance pulse oximetry detects pulsatile signals to measure oxygen saturation in capillary area, which is supplied by preductal vessel of fetuses in the vertex position. In the literature, the limits of oxygen saturation for critical fetal acidosis vary greatly. In this study, acidosis was defined as below the value of 7.09 for Umbilical artery (UA) pH or  $-10.50$  mmol/L for base excess.

In this study, we investigate the normality of the measured components, then decide the most informative components and finally obtain an indication of the adverse conditions by using local information content during intranatal monitoring. Section 2 presents theoretical contents and application to the intranatal case. Section 3 discusses experiments and results. Section 4 concludes the paper.

## I. INTRODUCTION

Clinical measurements of oxygen saturation of hemoglobin in arteries and veins have been dominated by the pulse oximetry, a noninvasive technology [1-6]. The spectroscopic measurement derives the information that hemoglobin and oxy-hemoglobin absorb light to varying degrees as a function of wavelength. Pulse oximeters distinguish the difference between optical absorption by blood and other anatomical constituents by observation that pulsating blood induces dynamics into absorption characteristics of well-perfused peripheral side. These dynamics are called photoplethysmograph (PPG) or blood volume velocity (BVP) and are used obtain measurements independent of optical properties of the skin, bone and nonpulsatile tissue. Pulse oximetry is well established as an early indicator of hypoxia during generally intensive care, recovery and anesthesia.

On the other hand, in fetal care, persistent fetal hypoxemia can lead to acidosis and neurologic injury and current

## II. METHODS

Local information content of a feature space is valuable for various applications . As a specific case, we consider the fetal oxygen saturation during labor and make use of accurate measurement of oxygen by reflectance pulse oximetry for noninvasive monitoring.

The study analyzes umbilical cord blood samples of 1537 live-born singleton neonates. Oxygen saturation was measurement by spectrophotometry, pH and base excess were measured by a pH and blood gas analyzer. Preductal oxygen saturation was calculated with an empirical equation. Acidosis was defined as below the value of 7.09 for UA pH or  $-10.50$  mmol/L for base excess.

### A. Gaussian Distribution

We first check the normality condition of fetal oxygen saturation. Normality condition of the parameters, the PH

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value and oxygen saturation of UA and UV is investigated by Kolmogorov-Smirnov test. Figure 1 and 2 show the histograms and how these histograms match to gaussian

distribution. It is observed that for a given population of the measurements we obtain an acceptable gaussian distribution with a reasonable tolerance level.

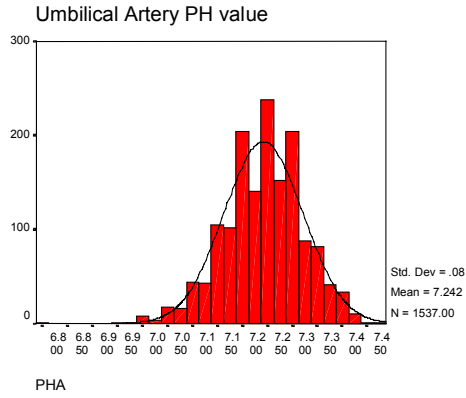
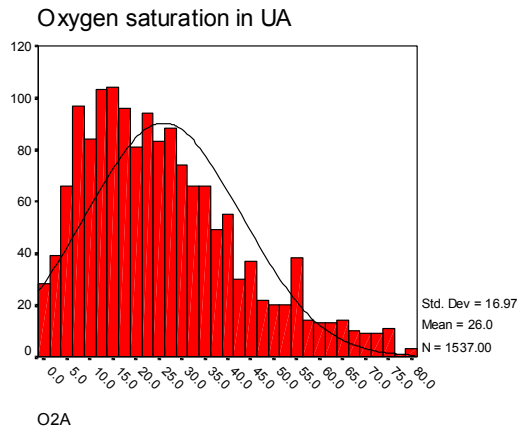


Fig. 1: Frequency distribution of umbilical artery pH values in 1587 vigorous human newborn infants; normal distribution,



O2A

Fig. 2: Frequency distribution of umbilical artery oxygen saturation values in 1587 vigorous human newborn infants; normal distribution

### B Principal Component Analysis (PCA)

We then apply factor analysis and try to find out the most informative oxygen saturation component of the intrapartum data. For this purpose, principal component analysis (PCA) [7] is used to find the most important and independent components from original data. Normally in PCA, a covariance matrix of the original data is created, and eigenvectors and eigenvalues of that matrix are computed. The original covariance matrix,  $\Sigma = E[(x - \mu)(x - \mu)^T]$  with  $x$  as the data set and  $\mu = E(x)$  as the mathematical expectation of the sample set, in practical cases is replaced by an estimated  $\hat{\Sigma}$ :

$$\hat{\Sigma} = \frac{1}{n} \sum (x - \mu)(x - \mu)^T \quad (1)$$

#### One-Sample Kolmogorov-Smirnov Test

		PHA
N		1537
Normal Parameters <sup>a,b</sup>	Mean	7.2420
	Std. Deviation	.7915E-02
Most Extreme Differences	Absolute	.048
	Positive	.026
	Negative	-.048
Kolmogorov-Smirnov Z		1.869
Asymp. Sig. (2-tailed)		.002

a. Test distribution is Normal.

b. Calculated from data.

#### One-Sample Kolmogorov-Smirnov Test

		O2A
N		1537
Normal Parameters <sup>a,b</sup>	Mean	26.0139
	Std. Deviation	16.9693
Most Extreme Differences	Absolute	.074
	Positive	.074
	Negative	-.063
Kolmogorov-Smirnov Z		2.905
Asymp. Sig. (2-tailed)		.000

a. Test distribution is Normal.

b. Calculated from data.

where  $x_i$  s are the sample vectors and  $\hat{\mu}$  is the estimated mean of the sample set. PCA uses eigenvalues  $\lambda_1, \lambda_2, \dots, \lambda_n$  of  $\hat{\Sigma}$  and the eigenvectors  $u_1, u_2, \dots, u_n$  of  $\hat{\Sigma}$  by choosing several of those eigenvectors that ensure preserving as much information as possible. This can be determined by the size of corresponding eigenvalues. The resulting reconstruction error or information loss is

$$R^2 = \text{trace}[D] - \text{trace}[D_M] = \sum_{n=M+1}^N \lambda_n \quad (2)$$

(D is the diagonal matrix of the eigenvalues). The mean-square reconstruction error,  $R^2$ , is achieved by accumulating those eigenvalues,  $\lambda_n$ , belonging to the abandoned

eigenvectors,  $u_i$ ,  $i=M+1, \dots, N$ . The ignored information or  $R^2$  becomes minimum if the smallest eigenvalues are accumulated.

The indices related to intranatal monitoring are 1:ThPre, 2:SaO<sub>2</sub> in UV, 3: pH in UV, 4:base excess in UV, 5:SaO<sub>2</sub> in UA, 6: pH in UA, 7:base excess in UA. The PCA orders the eigenvalues and confirms our expectation that base excess in UA, oxygen saturation (SaO<sub>2</sub>), pH turns out to be the most informative components (Fig 3). In fact, it is known that we obtain much of the information from the base excess in UA during labor.

### C. k-NN Algorithm

Finally, we employ local k-nearest neighbor (k-NN) [7-10] for the indication of adverse intranatal conditions. The concept of locality is related to the location of information that is extracted for class decision. The technique is in fact an approximation of Bayes Decision Theory in a local environment [7] and The process can further be extended to weighted voting and gaussian weighted voting (Parzen window). In k-NN rule, the class decision of unknown sample is based on the majority of the nearest k samples. In other way, a local voting process decides the class  $w_i$  of unknown sample  $x$  with the highest vote:

$$\text{If } k_i = \max \{k_1, \dots, k_L\} \text{ then } x \in w_i \quad (3)$$

$$k_1 + \dots + k_L = k$$

where  $k_i$  is the number of neighbors belong to  $w_i$  ( $i=1, \dots, L$ ) class among the k nearest neighbor. In practice to recognize pattern  $x$ , k minimum distance samples are computed among all the samples. Various norms of distance can be used: minkowski-norm-based distances, e.g. euclidian, mahalanobis and entropy or kullback-leibler distance.

Physical sense of closeness to a feature motivates us to use a local decision technique to investigate the adverse conditions during intranatal fetal oxygen monitoring. We assume that fetuses with asidosis create a cluster in the vector space. During the monitoring, this fact helps to make a decision of wellness.

### D. Radial Basis Function (RBF) Net

The RBF net [8-10] output produces an overall global decision by using the mean and covariance parameters of local basis functions. Physically, a single hidden layer network whose output nodes form a linear combination of the basis functions. A typical gaussian kernel function  $b(\cdot)$  is:

$$b_i(x) = \exp\left[-(x - u_i)^T C_i^{-1} (x - u_i)\right] \quad i = 1, 2, \dots, M \quad (4)$$

and the output layer node equation for the RBF:

$$y = \sum_i^M w_i b_i(x) \quad (5)$$

where,  $u_i$  is mean vector,  $C_i$  is diagonal covariance matrix and  $w_i$  is the weight value of the connection of the local kernel. As a result, the net, by its design structure, is able to produce a global decision out of gaussians that summarize the local information.

Further, the RBF net in nature becomes suitable for introducing the fuzziness to decision process [11]. For example, a gaussian basis function can be used to compute the local grade of fuzziness for the specific sample at the center.

## III. EXPERIMENTS

In this study, 1537 live-born singleton neonates were under observation. Oxygen saturation, pH and base excess values were measured, then preductal oxygen saturation were empirically found. Limit values of acidosis were below the value of 7.09 for UA pH or -10.50 mmol/L for base excess.

First, normality condition of the data is searched by Kolmogorov-Smirnov test and the normality of data is verified by a small error. Then, the importance of the information of individual factors is determined by using principal component analysis (PCA) method. The indices were 1:ThPre, 2:SaO<sub>2</sub> in UV, 3: pH in UV, 4:base excess in UV, 5:SaO<sub>2</sub> in UA, 6: pH in UA, 7:base excess in UA. The PCA shows (Fig.3) that oxygen saturation (SaO<sub>2</sub>), pH and specially base excess in UA reveals the most important information during the intranatal fetal evaluation.

Finally, the classifiers k-NN and RBF are employed for the indication of adverse conditions. k-NN, in terms of simplicity and performance, is proven to be a good choice as an indicator of wellness condition of fetuses during labor (Table 1). The RBF introduces a 97% sensitivity and 93% specivity.

## IV. CONCLUSIONS AND DISCUSSION

A new data processing method based on local information content is employed for pulse oximetry possessing the information related to oxygen saturation of hemoglobin for intrapartum fetal evaluation. As an intelligent data processing approach, hypoxia conditions of fetus are monitored and classified.

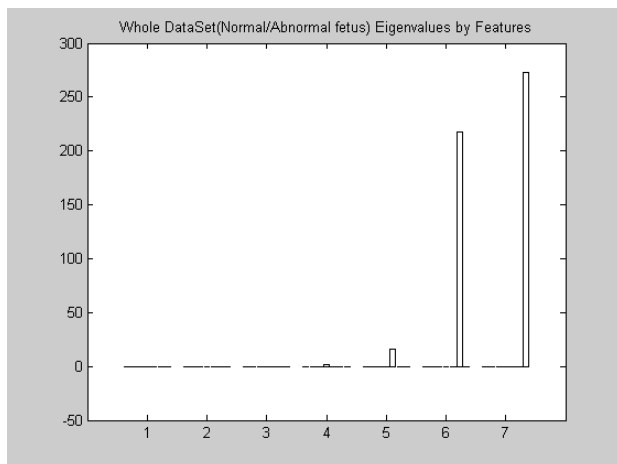
It is verified that the base excess in UA, oxygen saturation (SaO<sub>2</sub>), pH measurements are the most informative factors and the local information of oxygen saturation extracted by k-

NN helps to give an indication of adverse conditions during intranatal monitoring.

The study will continue to extend the leading the interpretation errors of pulse oximetry, the clinical alarm conditions and the other techniques to reveal local information.

	<b>Sensiti vity</b>	<b>Specifi city</b>	<b>PPT</b>	<b>PN T</b>
k- NN	92%	94%	95%	90 %
RBF	97%	93%	94%	96 %

**Table 1:**Results of experiments



**Figure 3:**The result of principal component analysis (1:ThPre, 2:SaO<sub>2</sub> in UV 3: pH in UV, 4:base excess in UV, 5:SaO<sub>2</sub> in UA, 6: pH in UA, 7:base excess in UA)

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